DOCSIS SET-TOP GATEWAY

Cisco Systems® support for the DOCSIS® Set-Top Gateway (DSG) brings intelligence and flexibility to the cable video distribution network. Incorporating out-of-band (OOB) messaging in DOCSIS digitally modulated carriers, cable operators can consolidate cable modem and set-top box (STB) data traffic on a shared DOCSIS channel. Cable operators can accelerate the rollout of new, bandwidth-intensive, interactive video services and migrate traditional, technology-based video networks to a standards-based IP network. Using a DOCSIS cable modem termination system (CMTS) to transport OOB messaging, along with data, simplifies operations, maximizes return on hybrid fiber-coaxial (HFC) plant investments, and accelerates deployment of advanced video services. The solution retains the essential nature of OOB messaging, but moves it to a modern technology base, rather than single-vendor, low-density, special-purpose equipment. A CMTS with DSG may be shared with data or dedicated for video and support one- or two-way operations.

OVERVIEW

Cable operators are evolving their video and data networks to an all digital converged network and planning to deploy advanced services, such as video on demand (VoD), switched video, on-line gaming and network based personal video recording (PVR) services to increase revenue and compete with satellite-based broadcast services. At the same time, home digital audio-video equipment such as DVD players is showing what is possible with simple, standards-based competitive consumer equipment sold through retail channels.

Cable and consumer electronics industries are about to take an important next step. An initiative accepted last year, called the Plug-and-Play agreement, created a uni-directional interface called point of deployment-host, which enables consumer electronics devices sold at retail to have the capability to decode premium programming through a conditional access system (CAS) module called a point-of-deployment (POD). This initiative enables consumers to purchase cable-compatible digital set-top boxes and integrated digital televisions at retail, and will eventually bring a variety of new and exciting applications into the home.

One area not in step with these developments is the core STB technology. Core STB technology has remained primarily proprietary in nature. That has locked cable operators into older video architectures, inhibiting their ability to take advantage of investments made in HFC plant upgrades and from benefiting from open standards-based equipment. This has hampered the introduction of high bandwidth-interactive services and kept equipment and maintenance costs high.

Considering the success of the DOCSIS standard for high-speed data services and the legislative stipulation in the Telecom Act of 1996 that mandates support for retail STBs, cable operators are now looking at adopting standards-based products for their digital video services to address competitive threats from satellite video operators. As part

of the CableLabs® OpenCable™ initiative, key changes are being introduced that affect the command and control transport mechanism between the STB and the headend; these changes take advantage of DOCSIS standards-based equipment and offer migration from traditional video equipment.

LEGACY SYSTEM

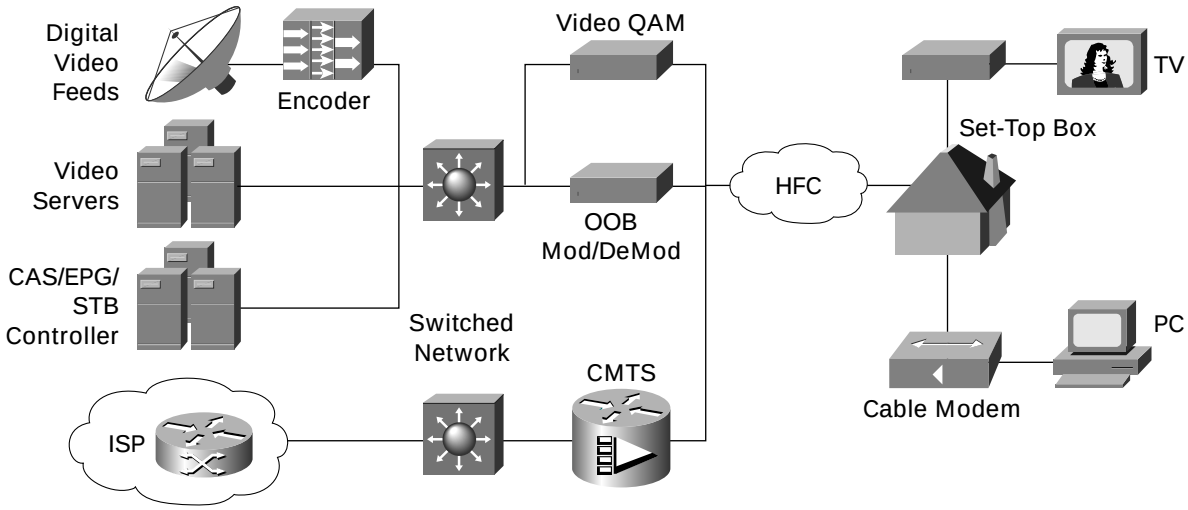
Existing STB technology relies on the use of a dedicated channel to transmit control messaging from the headend to each STB. Conditional access (CA), system information (SI), electronic program guide (EPG), emergency alert system (EAS) and other STB command and control messages are sent via a downstream radio frequency (RF) channel that is separate from the channels actually being watched—hence, the term *out-of-band* (OOB). A low bandwidth upstream reverse channel is used for interactive messaging.

The OOB carriers require separate, proprietary headend equipment such as out-of-band modulators and return path demodulators. The OOB channel is typically located in a reserved portion of the downstream HFC spectrum at 75.25 MHz and uses quaternary-phase-shift-keying (QPSK) modulation with 1.8 MHz of RF bandwidth. An OOB gateway in the headend system receives the content for the OOB channel over an IP/Ethernet connection from an application server, terminates the IP/Ethernet connection, and converts the content to ATM or MPEG-TS frames before passing the content down the OOB channel to the STB.

Most of the signaling messages from the application server are fed through another software program called a carousel and broadcasted on the OOB channel. The carousel repetitively sends out the messages from each application in sequence. The return path in such a system is typically operated through a polling mechanism over the OOB channel. The upstream transport, which has low bandwidth, is typically used to poll STBs for pay-per-view subscription information. The combination of the OOB channel downstream and the upstream return path resembles a primitive DOCSIS system.

Figure 1 shows a simplified representation of a cable video distribution network with traditional OOB-based equipment and a separate high-speed data (HSD) network.

Figure 1
Traditional Cable Video Distribution Network



MIGRATING OOB TO DOCSIS WITH DSG

To give the cable industry an alternative to proprietary set-top box technology, major cable operators and equipment vendors are rising to the challenge by introducing open, standards-based technology for video networks. As part of the CableLabs OpenCable initiative, Cisco Systems and a number of vendors have been working with a consortium of cable operators to specify an open architecture for cable headend equipment, application servers, and digital cable STBs.

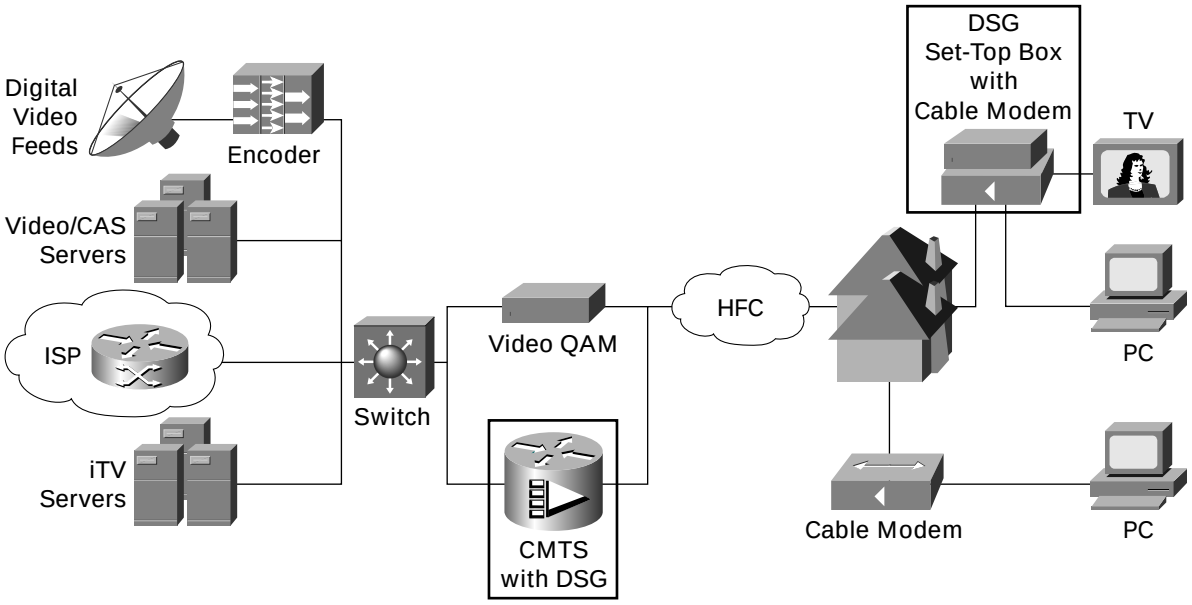
CableLabs, the standards organization laying the groundwork for traditional digital TV and new interactive video services, has developed the *DOCSIS Set-top Gateway (DSG) Interface Specification*. This specification defines interface requirements for transport of a class of service known as "out-of-band (OOB) messaging" between a set-top network controller, application servers, and customer premises equipment (CPE) such as residential gateways and STBs.

The DSG specification moves away from traditional proprietary OOB transport to widespread, IP-based technology, while preserving the essential nature of current OOB transport. The control information is carried on an "always-on" channel that is separate from the video delivery channel. DSG primarily offers the following benefits:

- Provides a robust transport path by continuing to provide downstream transport for OOB in case of a reverse channel impairment
- Allows cable operators to use DOCSIS networks to efficiently support new STB implementations by consolidating control traffic from the video network onto the DOCSIS network, thereby reducing operational costs
- Provides higher downstream and upstream bandwidth that will accelerate rollout of new interactive video services and in turn yield higher cable operator revenues
- Provides an evolutionary approach for existing headend applications to interoperate in a DOCSIS network, thereby preserving investment in headend systems; for example, conditional access systems (CAS), provisioning and billing systems
- Simplifies existing architectures and reduces capital expenses

Figure 2 illustrates a DSG-based network.

Figure 2
DSG-based Network



DSG uses a DOCSIS CMTS to carry the same OOB data to compatible STBs, eliminating the need to deploy and manage unique stand-alone OOB systems. DSG allows operators to take advantage of advances such as automatic ranging, built-in signal quality monitoring and telemetry. With only a software upgrade, a Cisco® CMTS can act as an intelligent gateway that interconnects the IP-based transport network, HFC cable network, and digital video systems. With a DSG-enabled CMTS, cable operators are now in a position to deploy innovative interactive services using best-of-breed advanced STB applications, and at the same time, consolidate their video control and data traffic. This creates a competitive edge for cable operators.

DSG ARCHITECTURE

DSG leverages the existing infrastructure of digital video and DOCSIS networks to enable broadcast and interactive services required for OOB messaging transport. The OOB messaging is meant to separate the quadrature amplitude modulation (QAM)-based digital video transmission mechanism from the security, access and feature complexity of advanced STB. DSG is not content-aware and it is this flexibility that makes DSG attractive. DSG allows entire STB provisioning and management systems that work in a system today to be reused with no modifications other than changing the physical transport. Fundamental design objectives of DSG are to:

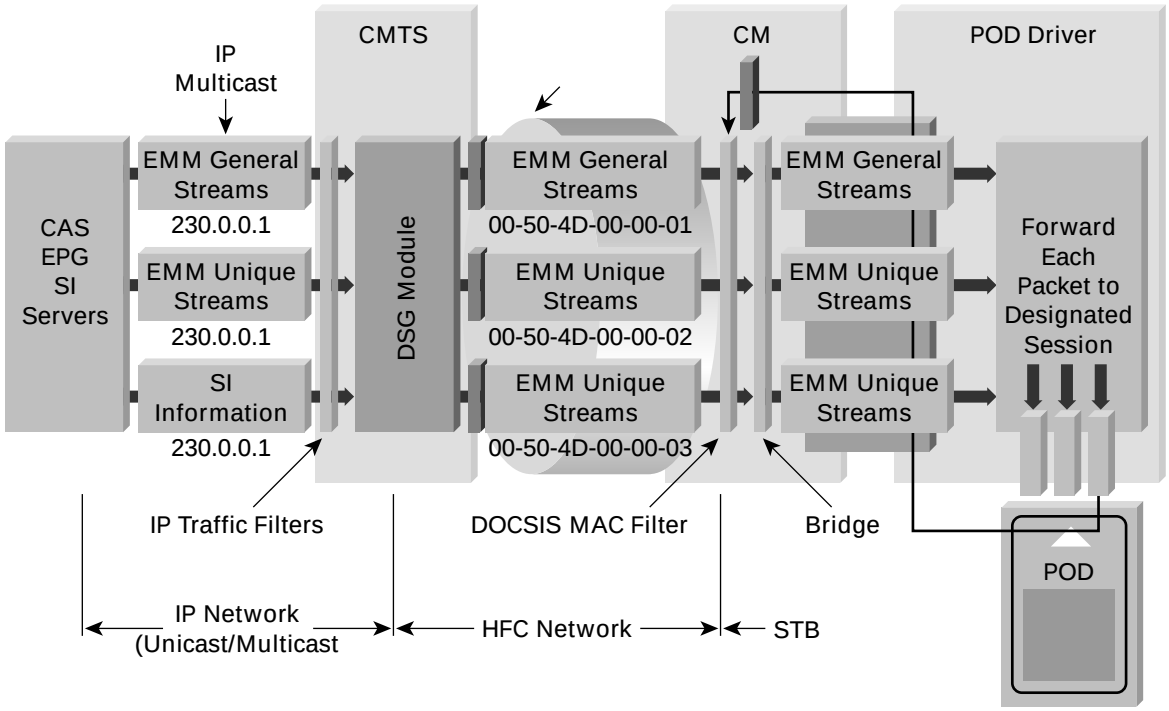
- Allow advanced STBs to operate in a one- or two-way cable plant and continue providing video services in case of reverse channel impairments
- Allow traditional STB network applications from the proprietary network and OpenCable set-top based applications to operate over a DOCSIS network

These objectives imply that the STB may or may not have an IP address. Furthermore, the STB is not dependant upon IP connectivity for OOB traffic from CMTS to the STB.

DSG is designed to operate under various plant constraints. It allows uninterrupted OOB transmission on the downstream, regardless of upstream channel availability. Running on a CMTS, DSG transports the downstream OOB data from video headend applications to the STB over a DOCSIS channel. Video streams continue to be transported through a separate channel over a QAM-based digital video transport. For reverse channel traffic, the advanced STB, equipped with a cable modem, communicates with the headend over the regular DOCSIS upstream channel.

Because of this, DSG can operate in both a two- or one-way plant. In a two-way plant, a STB using DSG can use the DOCSIS system upstream for transmitting interactive VoD and HSD traffic. The STB can continue to receive OOB traffic such as CAS and EPG if the upstream becomes impaired.

Figure 3
DSG Operation



Interfaces between the CAS and interactive application server follow either the standard as defined in OpenCAS (Society of Cable Telecommunication Engineers [SCTE] Digital Video Subcommittee [DVS] 278 and DVS 354) or they can be based on preexisting proprietary architectures.

Network Interface

The network-facing interface between application servers in the video network and the CMTS may be IP Multicast or IP Unicast. IP Multicast, which provides an efficient mechanism to distribute the same IP datagram to many receivers, is preferred over IP Unicast to distribute OOB content to the CMTS.

The DSG configuration ensures that the IP Multicast or IP Unicast traffic is mapped over to appropriate DSG tunnels, and in turn, to the right set of STBs or to an individual STB.

DSG Tunnel

The one-way IP datagram transport mechanism over which a CMTS communicates to a STB is known as a DSG tunnel. A conditional access or POD provider is limited to eight DSG tunnels to transport OOB messaging. A DSG tunnel is carried over one or more downstream DOCSIS channels and is identified by a well-known Ethernet media access control (MAC) address. This Ethernet MAC address is reserved and published by the conditional access or POD provider and can be either burned onto the POD or "smartcard" of the STB as in the DSG basic mode or can be dynamically sent to the STB as part of the Dynamic Channel Descriptor (DCC) MAC message referred to as "DSG advanced mode". Because the DSG advanced mode is not yet finalized in the CableLabs DSG Forum, this mode of operation is not discussed.

STB Initialization

When a DSG STB first boots, it scans the downstream for a QAM carrier. When QAM lock is achieved, the DSG tunnel client on the STB searches for a DSG tunnel with the DSG tunnel MAC destination address equal to the DSG client MAC address. If it finds at least one of the DSG tunnels, it stays on that downstream, regardless of any criteria necessary for two-way operation. It does, however, periodically try to achieve two-way operation.

DSG Operation

Each STB can receive data from up to four CAS vendors. DSG functionality on a CMTS provides a mapping of incoming IP datagram packets onto a specific DSG tunnel(s). This mapping is statically configured on the CMTS. DSG packets are forwarded through the CMTS and placed on the downstream channel. Before the packets are forwarded on the downstream channel, the MAC address of the DSG Ethernet frame is rewritten with the preconfigured destination MAC address of the appropriate DSG tunnel. Regardless of the type of address—IP Unicast or IP Multicast—the MAC address re-write mechanism can overwrite the Destination MAC Address field with the unicast MAC address or multicast MAC address as specified.

The application servers do not need to know the DSG client MAC address. Instead, the DSG servers send their content to a reserved IP address on the CMTS. If the connection from the DSG server to the CMTS is IP Unicast, then the IP destination address belongs to one of the subnets on the DOCSIS interface. If the connection from the DSG server to the CMTS is IP Multicast, the IP destination address is a Class D multicast address and the DOCSIS interface on the CMTS must be statically joined to that multicast group.

WHAT DO STANDARDS OFFER?

The OpenCable initiative, managed by the Advanced Platforms and Services Group at CableLabs, helps the cable industry deploy interactive video services over cable. Like several other CableLabs projects such as DOCSIS and PacketCable™, the OpenCable initiative provides a set of industry standards. OpenCable standards have three key objectives:

- Define the next-generation, digital consumer device
- Encourage supplier competition
- Create a retail hardware platform

CableLabs has published hardware and software specifications. The hardware specification allows a STB, which can be sold at retail, to interoperate across systems. The software specification of the OpenCable initiative, called the OpenCable Applications Platform (OCAP), addresses the problem of proprietary operating system software. OCAP creates a common platform on which interactive services may be deployed.

CableLabs defines the *DOCSIS DSG Interface Specification* (SP-DSG-101-020228) for enabling OOB messaging over DOCSIS networks. Further changes are being proposed to the original DSG specification, based on recent experiences gained by vendors and major operators during development and integration of DSG.

DEPLOYMENT SCENARIOS AND ECONOMICS

Essentially, DSG can be deployed in two scenarios:

DSG Inserted into Existing Video Network

DSG can be inserted into an existing video network with the goal of maintaining the video and HSD networks under separate operational domains. This deployment leverages the existing cable video plant layout and introduces higher bandwidth from DOCSIS downstream and upstream channels that can be used for rolling out bandwidth-intensive applications such as gaming, Web surfing, television-based or t-commerce, e-mail, chat, and targeted advertising, or supporting a higher density of STBs per hub.

Note: If the main goal is to deploy a larger number of STBs at existing traffic levels per STB, the number of STBs that can be deployed per downstream is limited by the node-combining limit driven by DOCSIS noise specifications. Introducing DSG with this goal alone may not be justified because of the increase in cost-per-STB involved.

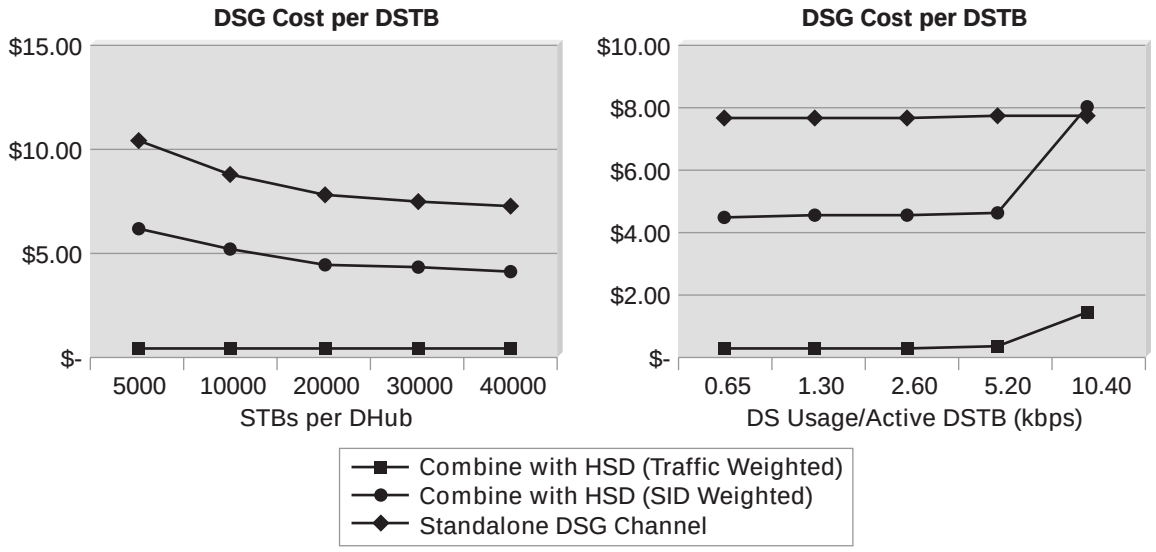
The best case scenario can be discovered by having an optimal mix of increased STB density with higher bandwidth per STB for interactive applications. Increases in revenue from new services will significantly offset the cost of STBs and make it an attractive proposition to migrate to DSG in this scenario.

Converged Video and HSD Network, Consolidating OOB and HSD Traffic on a Shared DOCSIS Channel

The second deployment scenario provides maximum benefits. Cable operators with HSD services can converge video and HSD networks by consolidating OOB and HSD traffic over a single DOCSIS network. In this scenario, an existing HSD channel can be shared for OOB and HSD traffic. Although the plant and spectrum topology are driven by HSD requirements (and thus fewer STBs are addressed per segment), significant savings from the consolidation of equipment and operations into one network make this a compelling option. Because the downstream and upstream bandwidth requirement for STB is small based on current STB applications, OOB traffic, in this scenario, fits neatly within an existing HSD channel, consuming relatively little bandwidth. Although service identifiers (SIDs) are consumed by STBs, SIDs are not a constraint in an HSD network. Moreover, DSG brings advanced monitoring and management capabilities of the DOCSIS system into the video infrastructure.

The graphs in Figure 4 analyze the cost-per-STB versus STB penetration and traffic usage under the previously mentioned scenarios: having a separate DSG channel or combining OOB traffic with HSD traffic. The analysis is based on a 50000 house holds passed (HHP), 500 HHP/fiber node cable plant consisting of STB data traffic of about 2.1 Mbps (700 kbps shared traffic such as EPG and CAS key information, plus an additional 0.65 kbps) per active STB for interactive communication, at 10 percent active usage), over a data plant providing 27 Mbps per 6 MHz channel downstream and 4.8 Mbps per 3.2 MHz channel upstream. The costs attributed to OOB traffic in the shared case are weighted by the share of traffic or by the share of SIDs used. In many cases, the cable operator may be able to leverage existing HSD DOCSIS equipment until DSG deployment is well under way.

Figure 4
Economic Models for Deploying DSG in Multiple Scenarios



As Figure 4 shows, consolidating OOB and HSD traffic over an existing HSD DOCSIS channel is financially very attractive. Cable operators have plenty of room for traffic growth new application deployment.

CURRENT MARKET SITUATION

The migration of OOB messaging traffic to an operationally superior and higher bandwidth DOCSIS channel is critical to adoption of interactive services such as VoD, T-commerce, gaming, and interactive TV. For these services, the traditional OOB mechanism (DVS 167 and DVS 178) is inefficient and provides insufficient bandwidth at a higher cost point. Moreover, market dynamics do not encourage further investment in this technology because it is insufficient to drive equipment costs down or support significant performance improvements. The DSG functionality on a CMTS enables efficiency and simplicity by sending OOB messaging over DOCSIS equipment.

Market acceptance for any new STB, such as those equipped with DOCSIS modems, has been limited in the past for several reasons, including:

- A new STB cannot require an all new STB provisioning and control
- A new STB cannot require new or additional RF spectrum to support a different CAS

Without addressing these challenges, any new STB cannot achieve the shipment volumes necessary to lower costs.

Current market dynamics are accelerating the demand for advanced STBs and tipping the market towards mass-market adoption. These forces include the following:

- Cable operator network upgrades are near completion; capital spending is shifting from plant upgrades to spending on new service deployments
- Introduction of OpenCable standards-based products, favorable regulations, and increased competition are driving costs of advanced STBs down. Sony's Passage system is one example of how an alternative STB and CAS solution can be developed without significant spectrum cost

- DSG shows how to deploy new, standards-based STBs that use existing provisioning system methods and messages

Countries such as Korea are leading the market in adoption of advanced STBs, creating in-country demand for DOCSIS-based CMTS products and complementary STBs. One of the main reasons Korea is leading in adoption of DSG is due to the greenfield cable video market and the absence of traditional systems. The Korea Digital Cable Forum, along with TTA—the regulatory organization in Korea—announced DSG adoption last year. Broadband Solutions Inc., (BSI)—a subsidiary of Powercomm, Korea—is now deploying DSG and plans to trial digital video services based on DSG this Spring.

Mainstream adoption in the United States is progressing fast as solutions are being defined for migrating traditional headend and STB equipment to DOCSIS-based DSG. Major cable operators overseas and in the United States are evaluating DSG-based equipment, thereby taking a major step towards migrating their networks to all digital converged network. The manufacturers that succeed in these new, highly competitive markets will be the ones that can quickly deliver advanced STBs that cost about the same as basic DOCSIS cable modems.

SUMMARY

DSG not only offers cable operators cost savings from consolidation of OOB video and HSD networks as their subscriber base grows, but it also opens up numerous opportunities to generate additional revenue streams from rollout of high bandwidth-intensive services. DSG provides digital video networks a gateway to sustained innovations of the DOCSIS standard, including advanced capabilities in spectrum monitoring, analysis, and network management.

The DOCSIS standard is clearly the standard of compliance and fundamental approach adopted worldwide to enable IP data, voice, and video services on an HFC network. The DOCSIS standard has facilitated interoperable CMTSs and modems, promoting an explosion in cable modem deployments. The DOCSIS standard created new revenue sources, aided by competitive pricing as modem prices dropped ten-fold.

The OpenCable initiative and DSG pave the way for similar advancements in video. Using DSG, cable operators can overlay operation of traditional STB technology and migrate to open-standards-based STBs. Cable operators can leverage their HFC infrastructure and DOCSIS CMTSs to consolidate cable modem and STB data traffic on a shared DOCSIS channel. Using DOCSIS and IP technology, operators can create integrated, multiservice HFC communications platforms capable of distributing high volumes of data, voice, and video from cable facilities to subscriber homes and offices.

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